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Vitamin D deficiency and total shoulder arthroplasty complications

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Abstract

Introduction: The primary objective of this study was to examine the relationship between vitamin D deficiency and implant-related and medical complications following total shoulder arthroplasty.

Methods: Using the PearlDiver database, patients who underwent total shoulder arthroplasty from 2005 to 2016 with vitamin D deficiency were identified. These were compared to a 3:1 control group matched by age, sex, and presence of a concomitant osteoporosis diagnosis. Primary outcome measures were implant-related complications (loosening, periprosthetic fracture, periprosthetic joint infection, and revision total shoulder arthroplasty) in addition to medical complications within 90 days of surgery. A multivariable logistic regression analysis was utilized to control for patient demographics and comorbidities.

Results: One thousand and six hundred and seventy-four patients with vitamin D deficiency were identified and compared to 5022 controls. There was a significantly higher rate of revision total shoulder arthroplasty in the vitamin D deficient patients compared to controls (2.3% versus 0.8%, odds ratio 3.3, $p < 0.0001$). After controlling for confounding variables, there were no significant differences in any of the remaining implant-related or medical complications with the exception of higher rates of urinary tract infections in patients with vitamin D deficiency.

Conclusions: Vitamin D deficiency is associated with a higher rate of all-cause revision total shoulder arthroplasty but not medical complications compared to controls.

Level of evidence: Level III case control study

Keywords

Vitamin D deficiency, total shoulder arthroplasty, complications

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Introduction

Vitamin D deficiency is a global problem that has the potential to affect all patient populations. In its active form, 1,25-dihydroxyvitamin D_3 plays a role in calcium homeostasis, bone metabolism, muscle function, and the function of the immune system. Vitamin D deficiency has been associated with chronic health conditions and is present in about 40% of the general population.[1–3] Likewise, there is a known high prevalence of vitamin D deficiency in patients undergoing orthopedic surgery. It is estimated that 39% of patients undergoing lower extremity total joint arthroplasty have vitamin D deficiency.[4]

An association has been identified between diminished outcomes in patients undergoing lower extremity joint arthroplasty with vitamin D deficiency.[5–11] Vitamin D deficiency has been found to be associated with decreased patient reported outcome measures including the Harris Hip score[7,10] and Knee Society Score.[9] There has also been a suggested association between vitamin D deficiency and periprosthetic joint infection (PJI).[11]

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There are no current studies examining a similar association of outcomes and complications with vitamin D deficiency for patients undergoing total shoulder arthroplasty (TSA), which has also been identified as a population at high risk of vitamin D deficiency.[12] The primary objective of the present study was to use a national database to examine the relationship between vitamin D deficiency and implant-related and medical complications following TSA. We hypothesized that there would be no association between vitamin D deficiency and postoperative complications including medical complications and implant-related complications. The eventual findings at least partially refuted our hypothesis.

Methods

Database

This database study was conducted under an exemption granted by our hospital's institutional review board. The study was deemed exempt because it involved the analysis of publically available, de-identified patient data. We utilized the PearlDiver (http://www.pearldiverinc.com) patient records database to query private-payer insurance patients in the United States (US) who underwent TSA with Current Procedural Terminology (CPT) code 23472 (Arthroplasty, glenohumeral joint; total shoulder (glenoid and proximal humeral replacement)) for a diagnosis of glenohumeral osteoarthritis. Only patients with a minimum of one year of postoperative database follow-up were included. Patients undergoing arthroplasty for chronic or acute fractures, or for rotator cuff tears were excluded. The database covers the years 2007–2016 at the time of this analysis, during which approximately 20,000 TSAs were performed. The private-payer database was chosen because it contains a larger age range of patients. Patients with perioperative serum 25-hydroxyvitamin D levels recorded within six months of surgery or an International Classification of Diseases, Ninth Revision (ICD-9) or Tenth Revision (ICD-10) diagnosis of vitamin D deficiency were included in the final study cohort.

Study and control groups

Patients were stratified into the vitamin D deficient group if they met either of the following criteria: serum 25-hydroxyvitamin D level less than 32 ng/ml or a diagnosis of vitamin D deficiency (ICD-9 268.9, ICD-10 E55.9). Further stratification of vitamin D status into deficient and insufficient was not possible due to the use of ICD-9 and ICD-10 coding to capture more patients; diagnosis codes only specify "deficient." The mean time prior to surgery for the vitamin D levels was 2.7 months.

A control group of patients undergoing TSA without vitamin D deficiency, defined as either a normal 25-hydroxyvitamin D level or absence of a vitamin D deficiency diagnosis code, was then identified and matched to the study group by age, sex, and presence of osteoporosis, which could be a significant confounder in this population. Using these matching criteria, a 3:1 control:study group match was possible and completed. Additional differences between the study and control group were controlled for using a logistic regression analysis which is described later.

Outcome measures

The primary outcome measures included implant-related complications, including loosening/lysis (ICD-9s 996.41, 996.45 and ICD-10s T84.038, T84.039, T84.058, and T84.059), periprosthetic fracture (ICD-9 996.44 and ICD-10s M97.3, M97.31-32, M97.8, and M97.9), and revision TSA (CPTs 23473 and 23474) identified within the database (up to nine years of follow-up). Postoperative infections occurring within two years of surgery were identified with ICD-9 and ICD-10 codes for diagnoses of postoperative or periprosthetic infection (ICD-9s 998.51, 998.59, 996.66, 996.67, and 996.69; ICD-10s T84.50 and T84.59). Cases with multiple codes for postoperative infection were considered single occurrences for the analysis. The study period included arthroplasty procedures performed from 2007 to 2016.

Using ICD-9 and ICD-10 codes, the following medical complications were identified within 90 days postoperatively: acute venous thromboembolism, in-hospital death, hospital admission, emergency department visit, urinary tract infection (UTI), pneumonia, myocardial infarction, acute renal failure, cerebrovascular accident, blood transfusion.

Statistical analysis

Comparisons of demographics and medical comorbidities were completed using chi square tests. Overall rates of medical and implant-related complications after TSA were calculated for both groups. These were then compared using a multivariable logistic regression analysis to control for patient demographics and comorbidities during comparisons. Patient demographic variables controlled for in the regression included sex, age, obesity (BMI 30–39.9 kg/m^2), morbid obesity (BMI 40+ kg/m^2), tobacco use, alcohol use, and the following medical comorbidities: osteoporosis,

diabetes mellitus, hyperlipidemia, hypertension, peripheral vascular disease, congestive heart failure, coronary artery disease, chronic kidney disease, chronic lung disease, chronic liver disease, thyroid disease, depression. Additionally, use of vitamin D/calcium medications or osteoporosis medications was queried and controlled for in the regression. Osteoporosis medications included forteo (and generic teriparatide), Evista, and the following bisphosphonates: etidronate disodium, Didronel, pamidronate disodium, Aredia, alendronate sodium, Fosamax, ibandronate sodium, Boniva, risedronate sodium, Actonel and zoledronic acid and Zometa. Odds ratios (ORs), 95% confidence intervals (CIs), and P values were generated from these regression analyses, with $P < 0.05$ considered statistically significant.

Results

One thousand and six hundred and seventy-four vitamin D deficient patients were identified and compared to 5022 age, sex, and osteoporosis diagnosis-matched controls. Overall, the groups were similar but had some statistically significant differences in comorbidities that were later controlled for in the regression analysis (Table 1).

Implant-related complications

There was no significant difference in the rate of implant loosening or lysis, periprosthetic fracture or periprosthetic fracture between study patients and controls. The rate of revision TSA within the database was significantly higher in the vitamin D deficient group (2.3%) compared to controls (0.8%), which was statistically significant (OR 3.32, 95% CI 2.17–5.09, $p < 0.0001$) (Tables 2 and 3).

Medical complications

There were no significant differences in any medical complications with the exception of the occurrence of UTI (Table 2). Patients who were vitamin D deficient were found to have a significantly higher risk of UTI compared to controls (OR 1.31, 95% CI 1.10–1.57, $p = 0.003$) (Table 3).

Discussion

This study was designed to investigate vitamin D deficiency as an independent risk factor for postoperative complications following TSA. Similar to the lower extremity arthroplasty literature, data from the present study suggest a link between vitamin D deficiency and all-cause revision TSA, even when controlling for osteoporosis and related medications.

Vitamin D has a central role in bone biology. The bony skeleton functions as an endocrine organ in helping to maintain calcium hemostasis owing to osteoblast receptors that respond to circulating levels of the active form of vitamin D.[3] In vitamin D deficient states, dietary calcium absorption is less efficient and circulating levels of parathyroid hormone are elevated which results in depletion of calcium from bones, leading to decreased bone mineral density and osteoporosis.[13] Recently, numerous public health initiatives have been aimed at identifying and treating high-risk populations for vitamin D deficiency. The problem is widespread, with vitamin D deficiency or insufficiency estimated to affect one billion people worldwide.[3,14]

Basic science studies have made efforts to evaluate how specific tissues and systems respond to vitamin D deficiency. Most studies in the shoulder relate to the rotator cuff. A mouse model was used to demonstrate that decreased serum levels of vitamin D resulted in poorer healing of rotator cuff tears.[14] This impairment of healing has been attributed to the inflammatory factor matrix metalloproteinase-9[15,16] which was shown to be elevated in the vitamin D deficient mice. Likewise, vitamin D has demonstrated an anti-inflammatory effect as it has been shown to downregulate the effect of tumor necrosis factor-alpha.[17] Oh et al.[18] showed a possible link between serum levels of vitamin D and increased fatty infiltration in rotator cuff tears which has been demonstrated elsewhere to correlate increased likelihood of irreparable rotator cuff tear.[19] Vitamin D deficiency has also been implicated as a risk factor for failure requiring revision surgery after rotator cuff repair.[20]

As mentioned above, the effects of vitamin D deficiency also appear to extend to the immune system. Several studies have demonstrated increased joint bacterial burden with vitamin D deficiency as well as a broad negative impact on immune system functions.[21–24] In the clinical application of proximal humerus fractures, vitamin D supplementation has been shown to improve the radiographic features of fracture callous formation.[25]

While there have not been prior studies involving outcomes in upper extremity arthroplasty, there have been a number of published results related to arthroplasty. In the lower extremity arthroplasty literature, vitamin D deficiency has been associated with poor results including decreased patient reported outcome measures like the Harris Hip score and Knee Society Score, as well as increased incidence of persistent pain following knee arthroplasty.[5–11] One study[26] contradicted these claims by asserting that there was no link to negative outcomes in the setting of vitamin D

Table 1. Patient demographics.

	Deficient/Insufficient (n = 1674)		Matched controls (n = 5022)		Comparison
	n	(%)	n	(%)	p
Demographics					
Age group					
Less than 50 years	16	(1.0)	48	(1.0)	1.000
50–59 years	97	(5.8)	291	(5.8)	1.000
60–69 years	477	(28.5)	1431	(28.5)	1.000
70–79 years	809	(48.3)	2427	(48.3)	1.000
80 + years	275	(16.4)	825	(16.4)	1.000
Sex (female)	1211	(72.3)	3633	(72.3)	1.000
African American race	114	(6.8)	274	(5.5)	0.040
Obesity (BMI 30–39.9 kg/m^2)	419	(25.0)	1208	(24.1)	0.420
Morbid obesity (BMI 40+ kg/m^2)	361	(21.6)	902	(18.0)	0.001
Tobacco use	523	(31.2)	1423	(28.3)	0.023
Alcohol abuse	76	(4.5)	231	(4.6)	0.919
Comorbidities					
Osteoporosis	737	(44.0)	2211	(44.0)	1.000
Diabetes mellitus	738	(44.1)	1919	(38.2)	<0.001
Hyperlipidemia	1451	(86.7)	4226	(84.1)	0.013
Hypertension	1483	(88.6)	4365	(86.9)	0.075
Peripheral vascular disease	306	(18.3)	866	(17.2)	0.334
Congestive heart failure	364	(21.7)	1012	(20.2)	0.162
Coronary artery disease	608	(36.3)	1802	(35.9)	0.746
Coronary kidney disease	496	(29.6)	1159	(23.1)	<0.001
Chronic lung disease	576	(34.4)	1733	(34.5)	0.941
Chronic liver disease	158	(9.4)	366	(7.3)	0.005
Thyroid disease	708	(42.3)	1683	(33.5)	<0.001
Depression	744	(44.4)	1993	(39.7)	0.001
Medications					
Vitamin D/Calcium medications	473	(28.3)	1112	(22.1)	<0.001
Osteoporosis medications	355	(21.2)	186	(3.7)	<0.001

BMI: body mass index.

Table 2. Complication rates for study group and controls.

	Vitamin D group			
	Deficient/Insufficient		Matched controls	
Complication	n	(%)	n	(%)
Implant-related complications within database				
Loosening/Lysis	21	1.3%	79	1.6%
Periprosthetic Fx	17	1.0%	50	1.0%
Periprosthetic Inf	21	1.3%	96	1.9%
Revision TSA	38	2.3%	42	0.8%
Medical complications within 90 days postoperatively				
Acute VTE	36	2.2%	100	2.0%
In-hospital death	0	0.0%	1	0.0%
Hospital admission	168	10.0%	467	9.3%
ER visit	316	18.9%	833	16.6%
UTI	194	11.6%	442	8.8%
Pneumonia	8	0.5%	26	0.5%
Myocardial infarction	7	0.4%	21	0.4%
Acute renal failure	80	4.8%	189	3.8%
Cerebrovascular accident	36	2.2%	127	2.5%
Blood transfusion	21	1.3%	56	1.1%

ER: emergency room; TSA: total shoulder arthroplasty; UTI: urinary tract infection; VTE: venous thromboembolism.

deficiency. In summary, there have been many instances in which a deficiency of serum vitamin D has been correlated with poor outcomes in orthopedic surgery, which is similar to the findings of the present study independently associating an increased risk of all-cause revision TSA with vitamin D deficiency.

While this study represents a new contribution to our growing understanding of serum vitamin D levels and their role in arthroplasty, it is certainly not without limitations. Many of these are inherent to the utilization of a national patient database: the potential for miscoding by practitioners, reliance on nonspecific infection codes, and lack of sufficient granular detail to make conclusions about optimal treatment strategies. As this is an insurance database, we do not have access to the actual operative reports or clinical charts. The CPT code used for inclusion (CPT 23472) includes both anatomic and reverse TSAs, so we excluded patients undergoing procedures for diagnoses other than primary glenohumeral osteoarthritis to create a rather homogenous population of primarily anatomic TSA, but it is likely that some reverse TSAs are included, but likely evenly distributed between the matched groups. As previous studies have done, to reduce the influence of nonspecific codes (i.e. those that do not specify the location of the infection), only infections occurring within two years of a TSA were included to maximize the likelihood that the infection was related to the surgical procedure of interest. Another limitation of the study methodology is that no additional patients could be added to improve statistical power. Some statistically significant findings were appreciated; however, it is likely that the study population was not sufficiently large enough to statistically power every endpoint or risk factor. Finally, this database is limited to the private-payer population, so the data above may not be generalizable to the entire US population.

Table 3. Statistical comparisons.

	Vitamin D group comparison	
	Deficient/Insufficient versus control	
Complication	OR (95% CI)	P
Implant-related complications within database		
Loosening/Lysis	0.80 (0.50–1.27)	0.337
Periprosthetic Fx	0.95 (0.53–1.72)	0.912
Periprosthetic Inf	0.66 (0.37–1.19)	0.196
Revision TSA	3.32 (2.17–5.09)	<0.0001
Medical complications within 90 days postoperatively		
Acute VTE	1.11 (0.78–1.59)	0.555
In-hospital death	n/a	
Hospital admission	1.10 (0.91–1.33)	0.317
ER visit	1.14 (0.95–1.37)	0.156
UTI	1.31 (1.10–1.57)	0.003
Pneumonia	0.87 (0.38–1.99)	0.300
Myocardial infarction	0.93 (0.38–2.31)	0.884
Acute renal failure	1.12 (0.84–1.50)	0.320
Cerebrovascular accident	0.90 (0.63–1.28)	0.567
Blood transfusion	0.95 (0.57–1.58)	0.833

CI: confidence interval; ER: emergency room; OR: odds ratio; TSA: total shoulder arthroplasty; UTI: urinary tract infection; VTE: venous thromboembolism.

Despite these limitations, this study has a number of strengths: inclusion of greater than 1600 patients with vitamin D deficiency, a surgical case selection recent enough to represent current surgical techniques, utilization of multivariate regression modeling to control for confounders, and report of previously unpublished findings that coincide with the findings in lower extremity arthroplasty literature.

Conclusion

Vitamin D deficiency is associated with a higher rate of all-cause revision TSA but not medical complications compared to controls.

Declaration of Conflicting Interests

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Ethical Review and Patient Consent

IRB was waived by our institution due to it being a study of deidentified, publically available data.

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